

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
26 July 2001 (26.07.2001)

PCT

(10) International Publication Number
WO 01/53862 A1

(51) International Patent Classification⁷: G02B 6/16, 6/44

20 Bromborough Road, Roseville, New South Wales 2069 (AU).

(21) International Application Number: PCT/AU01/00055

(74) Agent: GRIFFITH HACK; GPO Box 4164, Sydney, New South Wales 2001 (AU).

(22) International Filing Date: 19 January 2001 (19.01.2001)

(25) Filing Language: English

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(26) Publication Language: English

(30) Priority Data:
PQ 5183 20 January 2000 (20.01.2000) AU

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

(71) Applicant (*for all designated States except US*): JDS UNIPHASE PTY LTD [AU/AU]; 4a Byfield Street, North Ryde, New South Wales 2113 (AU).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): BULMAN, Jonathan, Mark [GB/AU]; 73 Ernest Street, Balgownie Heights, New South Wales 2093 (AU). INGLIS, Hugh, Gregory [AU/AU]; 264 Ellesmere Road, Gympie Bay, New South Wales 2227 (AU). PSAILA, David, Charles [AU/AU]; 82 Edgar Street, Kingsford, New South Wales 2032 (AU). POOLE, Simon, Blanchette [AU/AU];

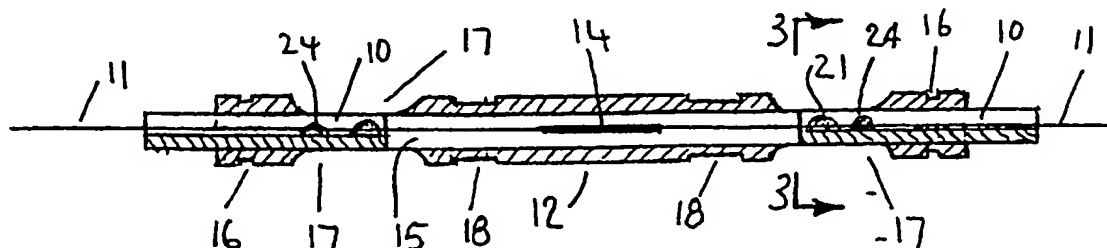
Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

BEST AVAILABLE COPY

(54) Title: PHOTONIC DEVICE PACKAGE



(57) Abstract: A photonic device/a method of forming a photonic device comprising a length of optical fibre [11] loaded in tension over a portion of its length, an in-fibre Bragg grating [14] formed within the tensile loaded portion of the length of fibre, two longitudinally spaced apart supports for the fibre [10], longitudinally aligned channels [19] in the supports, for receiving the fibre, a carrier [12] in which the supports are located, and glass solder [21] contained within the channel anchors the embedded fibre to the support, the supports being formed from a material that has a coefficient of thermal expansion greater than that of the glass solder.

WO 01/53862 A1

PHOTONIC DEVICE PACKAGEField of the Invention

This invention relates to a photonic device package
5 and, in particular, to a package that comprises an
in-fibre Bragg grating and a carrier for the grating.

Background of the Invention

A package of the type with which the present
10 invention is concerned must meet stringent requirements.
It must be capable of supporting an optical fibre (that
contains the Bragg grating) whilst the optical fibre is
strained to a level approaching 100 grams. The strain is
imposed for the purpose of tuning the grating to a
15 required centre wavelength, and the strain must be
maintained at a substantially constant level for the
service life of the grating. This requires that the
optical fibre be anchored securely within the carrier,
that the anchoring exhibit stability under varying
20 temperature and humidity levels, and that the package
exhibit dimensional stability with changes in ambient
temperature.

One package that has been developed in an attempt to
meet these requirements is disclosed in International
25 patent application number PCT/AU98/00473, dated 18 June
1998. The package comprises a temperature compensating
carrier in which an in-fibre grating is anchored by
deposits of epoxy resin.

This package has been found to provide long term
30 stability under optimum working conditions, but it does
exhibit slight sensitivity to changes in humidity levels,
this flowing from inherent characteristics of the epoxy
resin. An increasing humidity level causes a downward

- 2 -

shift in the centre wavelength of the grating, this making the package unsuitable for use, for example, in high channel count DWDM systems.

Various epoxy compounds have been evaluated in an attempt to resolve the humidity-induced problem, but none has shown any significant benefit over another.

Alternative approaches have been taken, using metal solder to anchor metal-clad optical fibre to supports. However, these approaches have resulted in packages that exhibit significant levels of creep over time.

The present invention has been developed in an attempt to avoid the above described problems and is based on the use of glass solder to provide for stable, humidity insensitive anchoring of optical fibre to supports for the optical fibre.

The selection of glass solder as the anchoring medium has led to the recognition that the supports should have a coefficient of thermal expansion ("CTE") that is higher than that of the glass solder, in order that compression might be induced in the glass solder during post-fusion solidification and simultaneous cooling of both the supports and the glass solder. Furthermore, it has been recognised that portions of the optical fibre that are bonded to the supports by the glass solder should be wholly embedded within the glass solder, and that the glass solder itself should be wholly contained (and hence restrained) within channels in the supports.

Various prior art references disclose the use of glass solder for hermetically sealing, bushing and terminating optical fibres and other photonic devices. In these contexts reference is made to United States patents numbered 4904046, 5143531, 5177806, 5337387, 5509952 and 5664040. Also, United States patent number 5682453

discloses the use of glass solder for bonding together first and second glass-based optical elements.

Perhaps more significantly, United States patent number 5694503 discloses an in-fibre Bragg grating that is
5 packaged to provide for reflectance that is substantially temperature independent. This package incorporates an Invar support member to which a length of optical fibre is secured by glass solder and epoxy bonding material. However, the support member and associated bonding
10 platforms are formed from a material having a CTE that is equal to or less than that of the glass solder.

Summary of the Invention

Broadly defined, the present invention provides a
15 photonic device package comprising a length of optical fibre which is loaded in tension over a portion of its length; an in-fibre Bragg grating formed within the tensile loaded portion of the length of the optical fibre, two longitudinally spaced-apart supports for the optical
20 fibre, longitudinally aligned channels in the supports for receiving the optical fibre, a carrier in which the supports are located and through which the length of optical fibre extends, and glass solder anchoring the optical fibre within the channel of each of the supports.
25 The glass solder is wholly contained within the channels of the respective supports, and portions of the optical fibre that are anchored to the supports by the glass solder are wholly embedded within the glass solder. Also, the supports are formed from a material that has a CTE
30 that is greater than that of the glass solder.

Although the package would normally include a single length of optical fibre, two or more lengths of optical fibre might be positioned in parallel within a single

carrier. In such case, each optical fibre may extend between and be anchored to an associated pair of longitudinally aligned supports or, in an alternative arrangement, multiple optical fibres may be extended
5 between and be anchored to one pair of supports.

The supports preferably are formed from metal, although they might be formed from a ceramic material. Also, the carrier preferably is fabricated from a metal, most preferably Invar, although, here again, the carrier
10 may be formed at least in part from a ceramic material.

The optical fibre may be pre-tensioned to induce a required level of strain and, thus, be anchored to the supports whilst, at the same time, being loaded in tension. Alternatively, the optical fibre may be
15 post-tensioned by permanently elongating the carrier after the optical fibre has been anchored to the supports or by moving the supports relative to the carrier before fixing the supports to the carrier. As indicated previously, the optical fibre is loaded in tension for the purpose of
20 tuning the grating to a required centre wavelength.

The channel in each of the supports may comprise a tubular channel but it preferably comprises a groove into which the glass solder is deposited to anchor the optical fibre. In this case the groove will have a depth
25 significantly greater than the diameter of the optical fibre in order that the optical fibre might be wholly embedded in the deposit of glass solder and the glass solder deposit might be wholly contained within the groove.

30 The carrier preferably is formed as a tubular housing in which the supports are located and through which the optical fibre extends. The carrier may be fabricated from a metal or a ceramic material. In the preferred form of

the invention the housing will be formed within its wall with at least one opening adjacent each of the supports, to permit deposition of the glass solder into the grooves in the respective supports. Two diametrically opposed
5 such openings preferably are provided adjacent each of the supports, one for accommodating deposition of the glass solder and the other to facilitate the application of fusing heat to the glass solder by way of the support. The glass solder may be in the form of a slurry or
10 sintered preform. A sintered preform is understood to be a unit of bonded glass powder, and has the advantage of allowing a measured dose of glass solder to be deposited in the channels.

The glass solder preferably is composed predominantly
15 of lead oxide (PbO_2), together with boron oxide (B_2O_3) and non-abrading glass fillers. Suitable fillers are titanium dioxide (TiO_2), silica (SiO_2) and zirconia (ZrO_2). The constituents of the glass solder should be selected to avoid surface abrasion of the optical fibre within the
20 deposits of the glass solder and, thus, the constituents should ideally have a smooth, spherical form.

The invention may also be defined as a method of assembling a photonic device package comprising a length of optical fibre which is loaded in tension over a portion
25 of its length, an in-fibre Bragg grating formed within the tensile loaded portion of the length of the optical fibre, two longitudinally spaced-apart supports for the optical fibre, longitudinally aligned channels in the supports for receiving the optical fibre, a carrier in which the
30 supports are located and through which the length of optical fibre extends, and glass solder anchoring the optical fibre within the channel of each of the supports; the supports being formed from a material that has a

- 6 -

coefficient of thermal expansion that is greater than that of the glass solder, the glass solder being wholly contained within the channels of the respective supports and portions of the optical fibre that are anchored to the supports by the glass solder being wholly embedded within the glass solder, the method comprising:

- longitudinally tensioning the optical fibre such that the in-fibre grating is tuned to a required centre wavelength;
- using glass solder to anchor the optical fibre to the supports.

The invention will be more fully understood from the following description of a preferred embodiment of a photonic device package. The description is provided with reference to the accompanying drawings.

Brief description of the drawings

In the drawings:

Fig. 1 shows on an enlarged scale a sectional elevation view of assembled carrier and fibre support components of the package;

Fig. 2 shows a sectional elevation view of the assembly of Fig. 1 mounted within a protective sleeve;

Fig. 3 shows (further enlarged) a cross-sectional view of the assembly as seen in the direction of section plane 3-3 in Fig. 1; and

Fig. 4 shows (still further enlarged) a perspective view of a portion of one of the supports when removed from the package.

Detailed description of the Invention

As illustrated, the photonics device package comprises two longitudinally spaced-apart supports 10 for

- 7 -

a length of optical fibre 11. The supports 10 are located within opposite ends of a carrier 12 through which the optical fibre 11 extends, and the carrier 12 is located within a protective sleeve 13.

5 The optical fibre 11 is formed within a portion of its length with a Bragg grating that is indicated schematically in Fig. 1 by the exaggerated fibre thickness 14, and the grating-containing portion of the optical fibre that extends between the supports 10 is loaded in
10 tension to an extent required to impose a requisite degree of strain in the grating-containing region of the fibre. The level of strain that is imposed will be dependent upon that required to tune the grating to a selected centre wavelength.

15 The carrier 12 is formed from a rod of low expansion material such as Invar and it is provided with a central bore 15 through which the optical fibre 11 extends. The supports 10 are located within the bore 15 and are held in place by welding through the carrier 12 at end regions 16.

20 Two diametrically opposed elongated openings 17 are provided adjacent each end of the carrier for reasons to be described later in this specification, and two longitudinally spaced, circumferential grooves 18 are provided to facilitate gripping of the carrier. The
25 reason for the grooves 18 will also be explained later in this specification.

As is most clearly shown in Figs. 3 and 4, each of the supports 10 comprises a generally cylindrical element that is formed along its full length with a longitudinally
30 extending groove 19. Also, the supports 10 are formed with flat lips 20 at each side of the groove, to coincide with side lands 17a of the upper openings 17.

The supports 10 can be formed from stainless steel, aluminium, or other any other material with a suitable CTE to ensure the glass solder is in compression.

The groove 19 within each support 10 has a depth
5 which is approximately equal to the radial dimension of the support. The optical fibre 11 is nested in the groove 19 in each of the supports 10 and is anchored in place by a deposit 21 of glass solder. There are two methods of attaching the optical fibre to the supports.

10 In the first method, the glass solder 21 is deposited in each of the grooves 19 after the optical fibre has been extended through the carrier 12, and the glass solder is subjected to localised heat. The glass solder is deposited within each of the grooves 19 by way of the
15 upper openings 17 and, thus, in the direction of arrow 22. The fusing heat for the glass solder is applied by focussing a CO₂ laser beam in the direction of arrow 23 through the openings 17 and against the underside of each of the supports 10. Thus, the glass solder is fused by
20 heat applied by way of the supports, this providing for good wetting of the solder-to-supports and minimising the risk of damage to the optical fibre. Of course, the normal acrylate (plastics material) cladding is removed from the portions of the length of the optical fibre that
25 are to be embedded within the solder glass deposits, in order to provide for solder-to-glass contact.

In the second method, the glass solder 21 is deposited in the grooves and the fusing heat is applied to melt the solder. The package is then raised so that the
30 suspended optical fibre 11 is immersed in the glass solder within the grooves 19. Alternatively, the optical fibre 11 can be lowered into the glass solder within the grooves 19 when the glass solder is molten. Once the fibre has

- 9 -

wetted to the solder, the heat is reduced to allow the solder to solidify, thus bonding the fibre to the supports 10.

A glass solder that is suitable for anchoring the optical fibre to the supports has the following (weight percentage) composition:

PbO₂ > 70
B₂O₃ > 5
10 SiO₂ > 1
ZrO₂ > 1
TiO₂ > 10

The glass solder composition has a fusing temperature . 15 below 550°C.

During the period when the glass solder frit is fusing and subsequently solidifying, the optical fibre is held under light tension, just sufficient to hold the fibre slightly above the base of the grooves 19 and to 20 permit the free flow of molten glass solder around the optical fibre.

In order to protect the packaged fibre from any external load that might be applied to the optical fibre, a plastics material clad portion of the optical fibre is 25 anchored within the groove 19 of each of the supports 10 by a deposit 24 of acrylate resin. The resin deposit is cured by exposure to UV radiation.

Following anchoring of the optical fibre 11 within the grooves 19 in the supports 10 and fixing the supports 30 to the carrier, the assembly as illustrated in Fig. 1 is gripped by way of the grooves 18 and is subjected to an elongating tensile load. The carrier 12 and the grating-containing portion of the optical fibre are thereby

- 10 -

elongated to an extent sufficient to induce a required level of strain into the grating-containing portion of the optical fibre. Alternatively the supports may be moved relative to the carrier to adjust the tension on the grating before fixing the supports to the carrier. The required level of strain to be induced in the optical fibre is detected by launching an optical signal into the fibre and detecting for peak reflectance of the grating at the required centre wavelength.

5 Having tuned the grating, the assembly as shown in Fig. 1 is inserted into the sleeve 13 and is enclosed by ends caps 25 that are press-fitted to end regions of the sleeve 13.

15 It would be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiment without departing from the spirit or scope of the invention as broadly described. The present embodiment is, therefore, to be considered in all respects
20 to be illustrative and not restrictive.

The claims defining the invention are as follows:

1. A photonic device package comprising a length of optical fibre which is loaded in tension over a portion of its length, an in-fibre Bragg grating formed within the tensile loaded portion of the length of the optical fibre, two longitudinally spaced-apart supports for the optical fibre, longitudinally aligned channels in the supports for receiving the optical fibre, a carrier in which the supports are located and through which the length of optical fibre extends, and glass solder anchoring the optical fibre within the channel of each of the supports; the supports being formed from a material that has a coefficient of thermal expansion that is greater than that of the glass solder, the glass solder being wholly contained within the channels of the respective supports and portions of the optical fibre that are anchored to the supports by the glass solder being wholly embedded within the glass solder.
2. The photonic device package according to claim 1 wherein the supports are formed from metal.
3. The photonic device package according to claim 1 wherein the supports are formed from a ceramic material.
4. The photonic device package according to any one of the preceding claims wherein the carrier is fabricated from a metal.
5. The photonic device package according to claim 4 wherein the metal comprises Invar.
6. The photonic device package according to any one of claims 1-3 wherein the carrier is fabricated from a ceramic.
7. The photonic device package according to any one of the preceding claims wherein the optical fibre is

longitudinally pre-tensioned before being anchored to the supports in order to tune the grating to a required centre wavelength.

8. The photonic device package according to any one of
5 claims 1-6 wherein the optical fibre is longitudinally post-tensioned after being anchored to the supports in order to tune the grating to a required centre wavelength.

9. The photonic device package according to any one of
10 the preceding claims wherein the channel in each of the supports comprises a groove into which the glass solder is deposited to anchor the optical fibre.

10. The photonic device package according to any one of
the preceding claims wherein each channel has a depth greater than the diameter of the optical fibre so as to
15 allow the optical fibre to be wholly embedded in the glass solder and to allow the glass solder to be wholly contained within the channel.

11. The photonic device package according to any one of
the preceding claims wherein the carrier is formed as a
20 tubular housing in which the supports are located and through which the optical fibre extends.

12. The photonic device package according to claim 11 wherein the housing is formed with at least one opening adjacent each of the supports to enable deposition of the
25 glass solder into in the channels in the respective supports.

13. The photonic device package in accordance with any one of the preceding claims wherein the glass solder is composed predominantly of lead oxide (PbO_2), together with
30 boron oxide (B_2O_3) and non-abrading glass fillers.

14. The photonic device package according to claim 13 wherein the glass fillers comprise one or more of the following compounds:

- titanium dioxide;
- silica; and
- zirconia.

15. A photonic device package substantially as herein
5 described with reference to the accompanying drawings.

16. A method of assembling a photonic device package
comprising a length of optical fibre which is loaded in
tension over a portion of its length, an in-fibre Bragg
grating formed within the tensile loaded portion of the
10 length of the optical fibre, two longitudinally spaced-
apart supports for the optical fibre, longitudinally
aligned channels in the supports for receiving the optical
fibre, a carrier in which the supports are located and
through which the length of optical fibre extends, and
15 glass solder anchoring the optical fibre within the
channel of each of the supports; the supports being formed
from a material that has a coefficient of thermal
expansion that is greater than that of the glass solder,
the glass solder being wholly contained within the
20 channels of the respective supports and portions of the
optical fibre that are anchored to the supports by the
glass solder being wholly embedded within
the glass solder, the method comprising:

- longitudinally tensioning the optical fibre such that
25 the in-fibre grating is tuned to a required centre
wavelength;
- using glass solder to anchor the optical fibre to the
supports.

17. The method according to claim 16 wherein the step of
30 longitudinally tensioning the optical fibre is carried out
before the fibre is anchored to the supports.

18. The method according to claim 16 wherein the step of longitudinally tensioning the optical fibre is carried out after the fibre is anchored to the supports.

19. The method according to any one claims 16-18 wherein
5 the glass solder is deposited in the channels in the form of a slurry.

20. The method according to any one of claims 16-18 wherein the glass solder is deposited in the channels in the form of a sintered preform.

10 21. The method according to any one of claims 16-20 wherein the step of anchoring the fibre to the supports comprises:

- depositing the glass solder in the channels;
- melting the glass solder;
- 15 - immersing the fibre in the melted glass solder.

22. The method according to any one of claims 16-20 wherein the step of anchoring the fibre to the supports comprises:

- inserting the fibre into the channels of the
20 supports;
- depositing glass solder in the channels around the fibre;
- melting the glass solder.

23. A method of assembling a photonic device package
25 substantially as herein described with reference to the accompanying drawings.

1/3

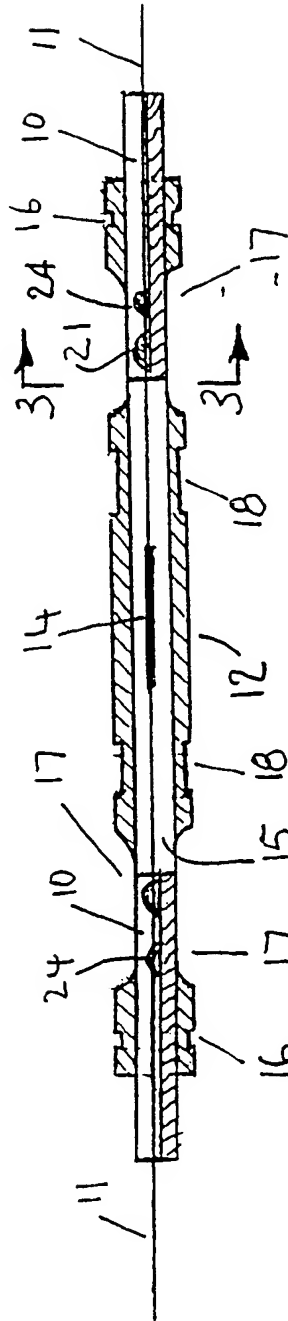


FIGURE 1

2/3

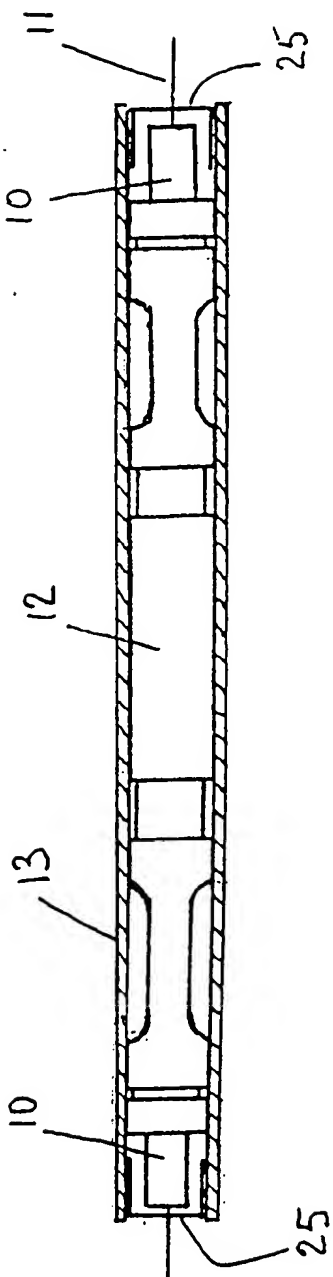


FIGURE 2

3/3

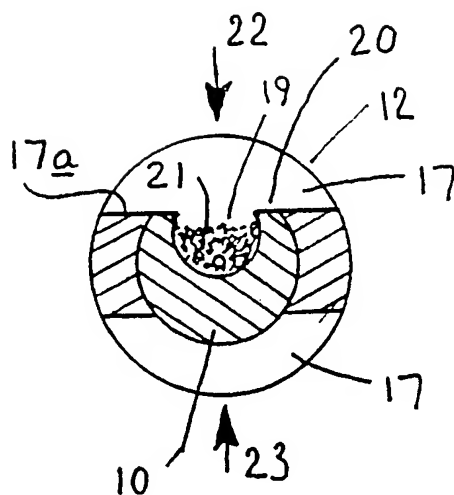


FIGURE 3

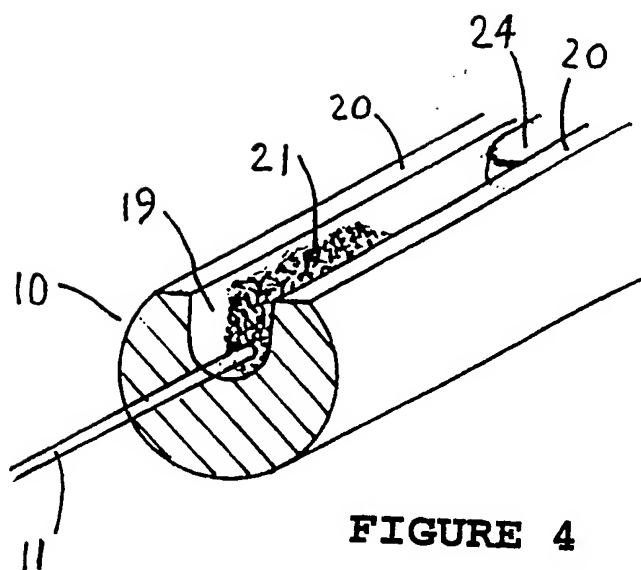


FIGURE 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU01/00055

A. CLASSIFICATION OF SUBJECT MATTER		
Int. Cl. ⁷ : G02B 6/16, 6/44		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) G02B 6/-, G02B 5/-		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) DWPI & JAPIO: (Glass+ OR PbO2 OR similar terms) AND (Bragg OR Fibre OR Fiber (W) Grating) AND (Temperature (S) Coefficient OR Temperature (S) Expansion) AND (Solder+ OR Frit+)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	WO 00/28361 A (CORNING INC) 18 May 2000 entire document	
A	AU 78988/98 (725267) B (JDS UNIPHASE PTY LTD) 4 April 1999 entire document	
P,A	Derwent Abstract Accession No 2000-665505/65, Class A89, CA 2293080 A1 (KUNG P) 23 June 2000 abstract	
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 13 March 2001		Date of mailing of the international search report 21 March 2001
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustalia.gov.au Facsimile No. (02) 6285 3929		Authorized officer MANO RAMACHANDRAN Telephone No : (02) 6283 2166

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU01/00055

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98/27446 A (MICRON OPTICS INC) 25 JUNE 1998 entire document	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU01/00055

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
WO	200028361	AU	64076/99				
AU	78988/98	WO	9859267	EP	990179		
WO	9827446	AU	47587/97	AU	48204/97	AU	53851/98
		EP	932814	EP	934501	US	5892582
		US	6044189	US	6115122	WO	9817968
		WO	9817969	US	5838437		
END OF ANNEX							

THIS PAGE BLANK (USP 10)

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☒ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.

THIS PAGE BLANK (USPTO)